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Rogowski electrodes for TEA lasers employing electroforming process

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Abstract. Electroforming process has recently become a viable technique for fabricating normal as well as complex metal shapes or configurations through electrodeposition. The present paper describes the technique for fabricating Regowski electrodes for TEA lasers by this process. The electrodes so made have shown hardness comparable to brass and stainless steel on mechanical test and have successfully been used in TEA CO_2 laser discharge. The technique is considered to be economical as compared to mechanical process and can readily be adopted when reproduction of these electrodes is required in numbers.

1. Introduction

Most of the TEA (Transversely Excited Atmospheric pressure) lasers like CO_2, HF and DF employ solid electrodes shaped to Rogowski profile (Rogowski 1923, Cobine 1958) in order to get uniform field distribution over the electrode surface to render uniform discharge. The present practice of making Rogowski electrodes is by mechanical process. The electrodes are normally solid or can be made hollow. The mechanical process is found quite cumbersome and time consuming specially when these electrodes are to be produced in large numbers.

The present paper describes a new technique for producing Rogowski electrodes by electroforming process. Electroforming has recently become a viable technique for fabricating complex metal shapes and configurations through electrodeposition. The electrodeposition is done on a mandrel of desired surface contour prepared by mechanical process which is subsequently separated from the electrodeposit. Electroforming has been found quite promising in order to meet sometimes very unusual physical and mechanical properties, extremely critical dimensions and tolerances, accurate reproduction of surface details and above all short production run to minimise high tooling cost involved in the mechanical process.

2. Fabrication of master electrode

In TEA lasers the electrodes (normally of aluminium alloy, brass or stainless steel) mush have a definite profile so as to provide uniform field distribution all over the surface. This profile is governed by Rogowski equation (Rogowski 1923, Cobine 1958). A special tool of high speed steel was made to generate this profile on the electrode. The technique for fabrication of Rogowski electrodes is described by Seguin (Seguin *et al* 1972) and the same method has been followed in the present case. The x, y coordinates for the tool profile (Figure 1) were scaled up suiting to the electrode width. An extruded aluminium alloy bar of dimensions $300 \times 30 \times 25$ mm. was used for the electrode. The profile was generated all along the four sides of the electrode. Sharp edges of the electrode were chamfered and the tool marks on the generated surface were eliminated with fine emery paper without upsetting the profile. Finally the electrode was hand polished or buffed. The master electrode is then cleaned with solvents to remove polishing materials from the surface. The Rogowski electrode so made is now ready for electrodeposition.

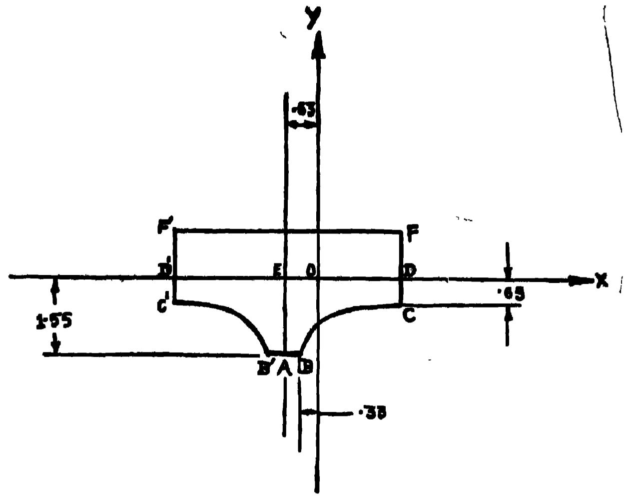

Figure 1. Profile of the tool blade with coordinates (in cms). These coordinates were further scaled up 20 times for making the template. The template profile is shown by ABCDE.

3. Electroforming process

Copper sulphate ($CuSO_4 \cdot 5H_2O$) and sulphuric acid are the primary constituents of electrolytic bath having composition : copper sulphate—225 gpl and sulphuric acid—70 mlpl which was chosen to yield optimum effeciency.

The bath was prepared by dissolving 45 Kg of copper sulphate in distilled water and adding 14 liters sulphuric acid slowly and at intervals in a Fibre reinforced plastic (FRP) tank. The bulk volume was made upto 200 litres by adding deionized water. The solution is heated upto 60°C with the help of 3 KW silica cased immersion heater and then allowed to cool overnight. The solution is finally filtered using a terylene cloth and transferred to another FRP tank.

The electrical connections for the electrolytic bath are shown in Figure 2. The master electrode or mandrel after having properly jigged (the back surface of the mandrel was masked with a nonconducting lacquer) was suspended in

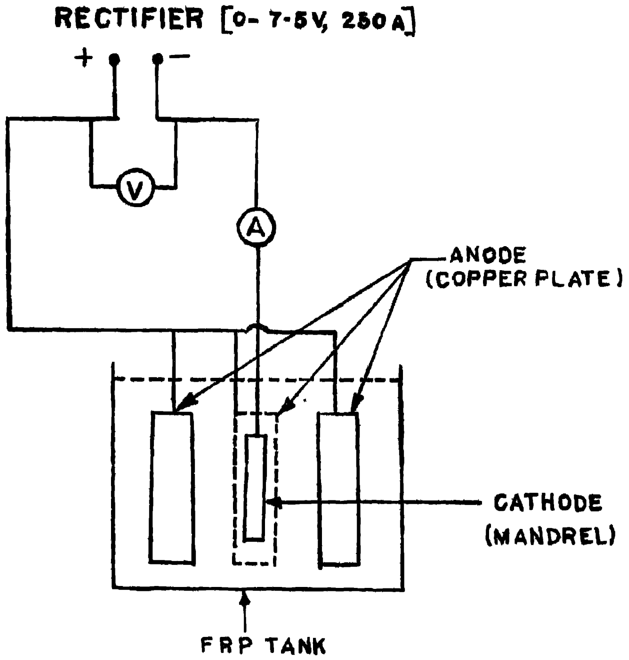

FIG. 2. ELECTROLYTIC BATH

the electrolytic bath and was connected to the cathode of the DC power supply (250 amperes and 7·5 volts). The other terminal of the power supply i.e., anode is connected to 3 copper plates dipped in the electrolyte facing the front surface of the mandrel. A DC voltmeter (0–5 V) and DC ammeter (0–100 A) were used to measure the operating voltage and current. The temperature of the bath was between 16–19°C. The electrolyte was agitated with the help of an air agitation unit. The electrolytic deposition of copper on the mandrel was allowed for about 16 hours (2 Volts, 10 Amperes). The mandrel is now taken out of the bath, cleaned with running water, dried and polished and finally plated with nickel-chromium.

The jigging part i.e. screws and suspension wires were removed from the mandrel. The lacquer is also cleaned with solvent. The electrodeposited copper on the sides of the mandrel is removed upto 2 mm from the bottom. The mandrel is now held on a vice and by application of slight mechanical force the electrodeposited part is separated out from the mandrel. Thus electroformed Rogowski electrode of copper with nickel-chromium plating was developed. This was subjected to mechanical test and performance trial in a double discharge TEA CO_2 laser.

4. Discussion

Having gone through the various aspects of electrolytic and mechanical process it is observed that the former has definitely several advantages over the latter technique. The surface hardness of the electroformed Rogowski electrode has been found excellent. Table 1 gives comparative data of surface hardness of electrodes of different metals.

Table 1. Surface hardness of Rogowski Electrode of various metals.

	Electrode		Surface hardness (H·V)
1.	Brass electrode	mechanical process	110–116
2.	Copper electrode		96–100
3.	Aluminium electrode		410–415
4.	Stainless Steel electrode		438–450
5.	Copper electrode—electroforming process		600–650

x	−0.330	0.305	0.280	0.255	0.240	0.205	0.180	0.155	0.125	0.100	0.075	0.050	0.025
y	−1.550	1.500	1.450	1.395	1.345	1.305	1.255	1.220	1.195	1.155	1.120	1.105	1.065
x	+0.000	0.025	0.050	0.075	0.100	0.125	0.155	0.180	0.205	−0.240	0.255	0.280	0.305
y	−1.040	1.015	0.990	0.965	0.950	0.925	0.915	0.900	0.875	0.865	0.850	0.840	0.825
x	+0.330	0.355	0.380	0.405	0.430	0.455	0.480	0.501	0.5035	0.560	0.585	0.610	0.635
y	−0.815	0.805	0.795	0.785	0.775	0.765	0.760	0.755	0.750	0.740	0.735	0.725	0.710
x	+0.660	0.685	0.710	0.735	0.760	0.785	0.810	0.865	0.890	0.915	0.940	0.965	0.990
y	−0.710	0.710	0.700	0.700	0.700	0.690	0.690	0.690	0.690	0.675	0.675	0.675	0.675
x	+1.015	1.040	1.065	1.090	1.120	1.145	1.220	1.245	1.270	1.395	1.525	1.650	1.780
y	−0.675	0.660	0.660	0.660	0.660	0.660	0.660	0.650	0.650	0.650	0.650	0.650	0.650

The main advantage of the electroforming process is that large number of electrodes can be produced using the same mandrel. The production rate can be further enhanced using several mandrels, without significant increase in the man power. It is obvious that volume of material and work involved in electroforming process is much less in comparison with the mechanical process. The electroformed electrode is extremely lightweight although the weight of electrode processed mechanically can also be reduced to some extent at the cost of additional labour and waste of material

A pair of electroformed electrodes was used in TEA CO_2 laser discharge which gave performance equally good as with solid electrodes.

The present technique is hence considered to be economical as compared to mechanical process and can readily be adopted when production of Rogowski electrodes is required in large numbers.

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